Coastal and Ocean Data Assimilation

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LONG-TERM GOALS

The long range scientific goal of this proposal is to produce optimal estimates of both the Lagrangian and Eulerian state space of the ocean, its marginal seas, and coastal zones in order to document, understand, and predict average conditions and variability. This is being accomplished through the use of data assimilation methods for ocean circulation models and Bayesian-based filtering techniques for Lagrangian prediction.

OBJECTIVES

Our primary objective is to develop new, multi-scale data assimilation algorithms for both Eulerian and Lagrangian prediction in coastal, ocean, and in transition regions that optimizes the information from measurements with different error and sampling characteristics. In particular, how to both combine and assimilate measurements that measure much different scales of motion in domains dominated by heterogenous, broad-band dynamics.

APPROACH

Our approaches are based on customizing, for Naval oceanographic applications, the latest developments in signal processing and Bayesian Analysis. In particular, the use of the reduced-order information filter (ROIF) for high-resolution data assimilative modeling, and the re-sampled particle filter (RSF) for the inverse Lagrangian prediction problem.

WORK COMPLETED

1) The (ROIF) data assimilation algorithm for the new HYCOM code is optimized and producing excellent results (see next section) in the HYCOM data assimilative modeling comparison (Srinivasan *et al.*, 2008).

2) An ensemble-based smoother with resampling was developed for strong nonlinear systems (Chin *et al.*, 2007).

3) A new class of stochastic boundary conditions for parameterizing sub-grid scale processes in numerical circulation models was published (Chin *et al.*, 2007).

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14. ABSTRACT
The long range scientific goal of this proposal is to produce optimal estimates of both the Lagrangian and Eulerian state space of the ocean, its marginal seas, and coastal zones in ordertodocument, understand, andpredict averageconditionsand variability. Thisisbeing accomplished through the use ofdata assimilation methodsfor ocean circulation models and Bayesian-based filtering techniques for Lagrangian prediction.

15. SUBJECT TERMS

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4) New techniques for computationally-efficient assimilation of Lagrangian data (Chin *et al.*, 2007; Molcard *et al.*, 2007).

5) Development and testing of the Re-sampled Particle Filter algorithms for inverse Lagrangian prediction problems (Chin and Mariano, 2008).

6) The LAPCOD book was finished and we Co-authored five chapters (Chin *et al., 2007*; Mariano and Ryan, 2007a,b; Molcard *et al.*, 2007; Piterbarg *et al.*, 2007) in *Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics*, Griffa, A., D. Kirwan, A.J. Mariano, T. Ozgokmen, and T. Rossby, editors, (2007, In press, Cambridge University Press).

7) The last paper of Haza's thesis on Gulf Stream-Slope water interaction was published (Haza *et al.*, 2007).

8) The last paper of Wilson-Diaz's dissertation that summarizes the seasonal heat budget in the Arabian Sea has been accepted for publication and is in press (Wilson-Diaz *et al.*, 2008). The details of this budget is a good benchmark for modeling studies in this area.

RESULTS

To make ROIF numerics more independent from a model's particular gridding scheme, the "ROIF inversion engine" has been converted by projection onto a set of continuous basis functions and it has been optimized by A. Srinivasan and colleagues for both MPI and OpenMP paradigms, and is now suitable for both shared and distributed memory machines. In general, the ROIF run is only about 3 times slower that the non-assimilating runs and this new development allows ROIF implementation to a high-resolution, global configuration of HYCOM.

Results from the optimized ROIF and other data assimilation algorithms for the HYCOM data assimilative modeling consortium shoot-out comparison are shown in figure 1. Compared to preliminary results shown last year, the new optimized ROIF is producing excellent results that are comparable to the benchmark runs with the Multivariate Optimal Interpolation (MVOI) scheme. These results are being finalized for publication by A. Srinivasan and co-authors (Srinivasan *et al.*, 2008).

The use of stochastic boundary conditions (SBCs) can energize the flow for a given Reynold's number in numerical circulation experiments. Presumably through a nonlinear cascades of scales, small amplitude, correlated noise applied at the western boundary can increase the total kinetic energy of the basin and produces velocity fields that exhibit more energy

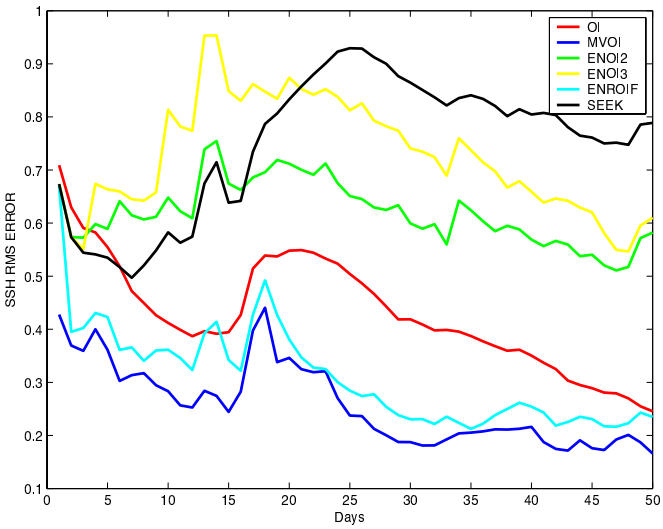

Figure 1: Root-mean-square error in estimating sea surface height as a function of assimilation time. The different methods were evaluated in the Intra-American Seas configuration as part of the HYCOM data assimilative consortium "shoot-out" between different methods. The ROIF technique produced similar error to the optimized MVOI method, even thought it started with a larger initialization error, and out-performed the other methods based on this test statistic.

throughout the frequency spectrum, even for low frequency. General auto-regressive stochastic models were used to generate the SBCs whose characteristics were determined from HF radar observations of coastal velocities (Chin *et al.*, 2007).

Results from the work using the particle filter on the inverse Lagrangian Prediction Problem are detailed in Chin's progress report.

IMPACT/APPLICATIONS

The application of Bayesian-based methods for Eulerian field and Lagrangian trajectory prediction in oceanography is the future of prediction methods for Navy operational needs. The use of SBCs is a fundamental new concept that can be generalized for many numerical modeling simulations of ocean and coastal flow.

The resampled particle filter can be used for deployment strategies for drifting acoustic sensors and to design Lagrangian-based optimal sampling.

TRANSITIONS

These results are being applied to the HYCOM data assimilative modeling consortium's effort to produce a reliable and efficient ocean forecast system for the Navy.

RELATED PROJECTS

This work is done in collaboration with A. Griffa, T. Özgökmnen, A. Srinivasan, and the HYCOM Data Assimilative Modeling Consortium.

PUBLICATIONS (2006-2008)

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